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Site-specific Farming 6

Collecting sensor data.
(Courtesy of Brian Arnall, Oklahoma State University, used with permission.)

Active-optical Ground-based Sensor Algorithms as Tools for Determining Top-dress Nitrogen Rate

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A scientific approach for determining spring wheat top-dress N rates

Active-optical light sensors have been available for agricultural use for nearly 30 years. People are most familiar with passive light sensors. A passive light sensor is a sensor that can detect visible light and other electro-magnetic radiation emitted by the sun that is reflected and sensed by the instrument. Examples of passive light sensors are aerial photography and satellite imagery. An active-optical sensor emits its own light in specific wavelengths and has the ability to measure the intensity of the light reflected from the target (plant canopy) into the instrument compared to the light the instrument emitted.

The active-optical sensors that relate to this publication have the ability to filter out ambient light through their modulated light pulses. The modulated light pulses are similar to light-based UPC codes found on food packaging, based on the length of their on-off patterns. The sensors read only the light received in the same modulated pattern. The readings the instrument records are not influenced by changes in sunlight, cloud cover, or passing clouds, and therefore provide similar readings whether they are used at night or during the day. The only conditions that disrupt measurement consistency is leaf wetness from rain, recent irrigation or early morning dew.

The two active-optical sensors recently tested in spring wheat nitrogen (N)-rate trials are the GreenSeeker (Trimble, Sunnyvale, California) and the Holland Scientific Crop Circle (Holland Scientific, Lincoln, Nebraska). The algorithms developed using these instruments utilized N-rate research performed in North Dakota during the past decade. The GreenSeeker is based on a red sensor with 660nm wavelength and near infrared with 770nm wavelength. The Crop Circle red sensor is based on red 670nm wavelength and near infrared with 760nm wavelength. The Crop Circle red edge sensor uses the same near infrared 760 nm wavelength, and the red edge band is 730nm wavelength.

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Top-dress Algorithms

To use an active-optical sensor for the purposes of site-specific N top-dress application in wheat, an N-sufficient area in the field must be established. The area should be in a soil typical of the field, usually the width of the fertilizer applicator, about 100 feet long, and located in an area close to the field entrance but not in the end-rows. If all of the N calculator (refer to reference or website) recommended N was applied preplant (at or near planting), then an additional 50 pounds N/acre should be applied in the N-rich strip area. If only half of the recommended N was applied preplant or at planting, then 100 pounds N/acre should be applied to the N-sufficient area.

At the time of topdress, the growing degree days from planting date should be entered into the controlling computer unit. This is necessary to standardize the data through the calculation of INSEY (in-season-estimate of yield). The INSEY is a standardization that allows the application to be made plus or minus one wheat leaf stage from V5 (5-leaf wheat growth stage), for which the algorithm was developed. When the applicator enters the field with the sensor or sensor array attached in front of the applicator unit, it first senses the N-sufficient strip. The average reading from the area is entered into the spray controller. If the readings in the rest of the field are within 5% of the N-sufficient strip, then no rate of N would be expected to increase yield more than the yield in the N non-limiting area. **If the readings in the field are greater than those in the N-sufficient strip, it is very likely that sulfur (S) deficiency is present in the field, and this has to be addressed before using the system to apply additional N fertilizer.** Sulfur sources would be ammonium sulfate granules, streamed ammonium sulfate solution or streamed ammonium thiosulfate. Application should be followed by rainfall, then the field should be rescanned.

If the field readings are less than the N-sufficient strip by more than 5%, the algorithm will reasonably predict the lower yield probable if no N was applied. The difference between yield predicted in the N-sufficient strip and the yield predicted outside the N non-limiting area is used to calculate the N rate.

1. **Scan N-sufficient strip.**
2. **Determine INSEY of strip (scan reading divided by growing degree days from planting to scan date).**
3. **Scan area outside the N-sufficient strip (this can be done site-specifically or as a field if that is not practical).**
4. **Determine INSEY of average scan outside the N-sufficient strip.**
5. **Apply N-sufficient strip INSEY and INSEY outside the strip to the yield equation provided in table.**
6. **Determine N required to attain yield near that predicted for the N-sufficient strip.**
   Yield difference (bu/acre) X 60 pounds per bushel X 2.25% N in the grain = (N required for the additional yield)
7. **Divide N required by the efficiency factor of 0.6 for topdress.**
8. **The answer is the N rate for topdress.**

An additional algorithm factor is the consideration of areas in the field that have low plant density, bare areas, areas with poor growth due to high salts or non-N nutrient problems. If the INSEY falls below 0.00025 for a Red NDVI sensor, or 0.00012 for a RedEdge NDVI sensor, then the poor growth is not the result of low N, and the rate applied to the area should be zero supplemental N.

Spring wheat algorithm inputs for the use of GreenSeeker and Holland Scientific Crop Circle sensors in North Dakota spring wheat yield prediction for use in directing top-dress N rates

Conventional Till

Sensor	NDVI Source	Growth Stage	Yield Prediction Formula	Minimum INSEY for N rate
GreenSeeker	Red	V5	Yield = (187,853 X INSEY) - 56	0.00025
Crop Circle	Red	V5	Yield = (186,405 X INSEY) - 51	0.00025
Crop Circle	Red Edge	V5	Yield = (352,501 X INSEY) - 38	0.00012

No-till (six years or more continuous)

Sensor	NDVI Source	Growth Stage	Yield Prediction Formula	Minimum INSEY for N rate
GreenSeeker	Red	V6	Yield = (205,831 X INSEY) - 39	0.00025
Crop Circle	Red	V6	Yield = (97,752 X INSEY) + 12	0.00025
Crop Circle	Red Edge	V6	Yield = (157,555 X INSEY) + 19	0.00012

Example of algorithm calculation:

A field near Carrington in 2020 was soil sampled in fall 2019, and using the N-Calculator for spring wheat and durum https://www.ndsu.edu/pubweb/soils/wheat/, the N recommendation was about 100 pound N per acre. Spring wheat was seeded in 2020 on April 15. Fifty pounds of N per acre was applied to the field before planting, with an additional 100 pounds of N per acre (150 pounds N per acre total) applied to an N-sufficient strip. The date of 5-leaf-stage scanning for top-dress was May 30. NDAWN indicated that the Growing Degree Days (GDDs) of this interval for wheat was 836 GDD.

1. The scan of the N-sufficient area showed an average GreenSeeker red NDVI reading of 0.636.
2. The INSEY for the N-sufficient strip would be 0.636/836 = 0.0007608.
3. In another part of the field outside of the N-sufficient strip, GreenSeeker red NDVI reading was 0.56.
4. The INSEY for 0.56 is 0.56/836 = 0.0006699.
5. In N-sufficient strip, the relationship of GreenSeeker red NDVI to yield is:
   Yield = 187853 X INSEY – 56
   For N-sufficient strip, 0.0007608 x 187853 = 142.9
   142.9 – 56 = ~87 bushels wheat per acre predicted for the N-sufficient strip
   Yield prediction outside the N-sufficient strip is (0.0006699 x 187853) – 56 = ~70 bushels per acre
6. The difference in yield between the N-sufficient strip and outside the strip is 87-70 = 17 bushels per acre.
   Percent N in 14% protein wheat is 2.24% N
   N contained in 17 bushels of wheat at 14% protein is 17 x 60 x 0.0224 = 22.8 pounds N per acre.
7. The efficiency of topdress is usually about 60%, so the N required for wheat yield to be similar as the N-sufficient strip is 22.8/0.6 = 38 pounds N per acre.
8. The N rate outside the N-sufficient strip is 38 pounds N per acre.

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